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Colvin

ENGINEERS ARITHMETIC

▼ ▼ ▼

A Pocket Book containing the foundation principles involved in making such calculations as comes into the practical work of the stationary engineer.

▼ ▼ ▼

BY

FRED H. COLVIN AND
WALTER LEE CHENEY

▼ ▼ ▼

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PREFACE.

This is by no means a complete guide to steam engineering, but rather a stepping-stone for those who may not be familiar with the calculations used.

Calculations, and especially formulas, are sometimes stumbling blocks that prevent good men's progress, and it is to remove these obstacles, by showing *how* each calculation is made, as well as *why* we do it, that this little book has been prepared.

While this does not show nearly all calculations used, it contains enough to enable any one to work out other rules or formulas which come up from time to time.

ENGINEERS' ARITHMETIC.

Decimals.

There are few men who do not understand vulgar or common fractions, as it is plain that ½ means one-half, ⅜ means three-eighths, etc., and in plain language we say that the figure below the line (or denominator) shows the number of parts into which the number (or whatever is being considered) is divided, and the figure above the line (numerator) shows how many of these parts are being spoken of.

Decimals or decimal fractions are a *system* in which ten is the base (derived from *decem* meaning *ten*), and is not a fundamental principle.

In this everything is reduced to tenths, hundredths, thousandths, etc., and the value is determined by the position of the decimal point.

Taking the number .125 and we read the first figure as tenths, second as hundredths, etc.; and as there are three figures the value must be 125 thousandths or $\frac{125}{1000}$, the position of the point indicating the value of the decimal fraction.

Moving the point between the 1 and 2 we have 1.25, which makes 1 a whole number and $\frac{25}{100}$ the fraction.

Moving it again in the same direction we have 12.5 or 12 and $\frac{5}{10}$. We see then that moving the point to the *right* multiplies by ten for every place it is moved (and consequently that moving it to the left would *divide* by ten in a similar manner), and that we can divide or multiply by ten by simply changing the position of the point.

If we have common fractions it is very easy to change them to decimals by dividing the numerator by the denominator, as in the case of ½ we have $2\underline{)1.000}=.500$ or $\frac{5}{10}$.

Take the numerator and place a decimal point after it, adding as many ciphers as are likely to be needed, four being a very common number to add, as four de-

cimal places (or ten thousandths) are usually accurate enough for most calculations.

When we have $\frac{1}{64}$ to reduce to decimals it is simply an example in long division, the placing of the point being the main thing, and we simply divide 1.0000 by 64 which equals .0156 or 156 *ten thousandths.*

It should be thorougly understood that there is no *principle* involved in using this point, it is merely a custom or system (although a very useful one), but as we find time tables in which 9.10 means ten minutes past nine, although ten minutes equals $\frac{10}{60}$ instead of $\frac{10}{100}$ as in the case of decimals, we see this is always a custom and not a fundamental principle.

Although it is customary to use common fractions in many shops, the use of finer measurements, such as hundredths and thousandths, makes it convenient to have a table showing the fractions ordinarily used and their equivalents in decimals, and a table of this kind is given at the end of this chapter.

Knowing that all figures to the right of the decimal point are decimal parts of

one (no matter what) and that all figures to the left are whole numbers it will be readily seen that in addition and subtraction we place the figures so that the decimal points come under each other, as,

Adding	or subtracting
2.1347	4.3257
2.2532	2.17857
4.3879	2.14713

Never mind the number of figures in the decimal, place the points in line, add ciphers (either mentally or in reality) to make them even, and proceed as in ordinary calculations.

In multiplication we pay no attention to the relative positions of the decimal points, but multiply as usual and point off in the product as many places as there are decimals in *both* the multiplier and multiplicand, counting from the *right.*

As an example we have 3.125 multiplied by 1.25, or,

```
 3.125
  1.25
------
 15625
 6250
3125
------
3.90625
```

There being three places in one and two in the other we count off five (two plus three) from the *right* and place the point between the 3 and 9, making the result 3 and $\frac{90625}{100000}$.

The reason for pointing off in this manner will be clear if we study the question a little. Taking the example above we find the whole numbers to be 3 and 1 and it is evident that the result cannot be either 0.390625 or 39.0625, but must be more than 3 and less than two figures, as in the last number above.

Taking the numbers 3.9×4.8 it is evident that the answer will be more than $3 \times 4 = 12$ and less than $4 \times 5 = 20$, as the numbers are less than 4 and 5.

$3.9 \times 4.8 = 18.72$ with two figures pointed off in accordance with both rule and reason.

It has probably been noticed that in placing the denominators under decimals (in order to make their value clear) we put a figure 1 at the left and as many ciphers to the right as there are figures in the decimal.

In the case first mentioned we place

five ciphers to the right of the point, making it "hundred thousandths."

We have given these denominators to make the value of the decimal more clear, although in actual practice it is never done, the value being easily reckoned mentally by calling the point 1, and adding ciphers as before stated.

Division of decimals is very easy, after you learn to neglect the decimal point while you are dividing, and then to put it in the right place in the quotient (or answer).

Divide as with simple numbers and point off as many places in the quotient (answer) as the decimal places of the dividend (number divided) exceeds the decimal places in the divisor.

If the decimals in the divisor exceed those in the dividend, add ciphers to the right of the dividend as far as necessary, taking care to count only those *used*, when placing the decimals in the answer.

Division being the reverse of multiplication it seems almost self-evident that pointing off should also be reversed.

If the reasons given before are tho-

roughly understood this will be made plain without difficulty.

Divide 3.24 by 1.2.

```
1.2)3.24(2.7
    2 4
    ---
     84
     84
     --
```

And as there are two decimal places in the dividend and only one in the divisor, we point off one place from the right in the answer.

Take another case and divide 3.1478 by .071

```
.071)3.1478(44.3+
     2 84
     ----
      307
      284
      ---
       238
       213
       ---
        25
```

Forget all about the decimal points in the divisor and proceed as before. Then as there are three decimal places in the divisor and four in the dividend we point off one from the right and have 44.3 for an answer. This can be carried further by adding ciphers to the dividend, which will

evidently not alter the *position* of the decimal point in the least, but will simply carry the answer to more decimal places.

Not wishing to carry the division to more decimal places and as it does not come out even we put a plus sign (+) after the quotient, showing that it is incomplete.

It does not matter if the divisor is larger than the dividend, as in dividing .00237 by .0921

```
.0921).002370000(.25732+
        1842
        ----
         5280
         4605
         ----
          6750
          6447
          ----
           3030
           2763
           ----
            2670
            1842
            ----
```

We add four ciphers and make nine decimal places in the dividend, and as these exceed the decimals in the divisor by five places we must point off five places from the right and place the point before the 2.

If you have any doubt as to its correctness, multiply the answer by the divisor and the result should give the dividend.

It is well to prove work in this way if you have any doubts in the matter.

To divide .3987 by 125.2

```
125.2).3987000(.003184+
        3756
        ----
         2310
         1252
         -----
         10580
         10016
         -----
           5640
           5008
           ----
            632
```

We have added three ciphers to the dividend, making seven decimal places, and as there is but one decimal place in the divisor, the quotient must have seven minus one, or six places. As there are but four figures in the quotient we must make the six by adding two ciphers to the left (in front) of the quotient and placing the point in front of the ciphers, making the answer .003184. It will be seen that placing ciphers to the right would not alter the value of the decimal in the least.

Divide .96 by .08

```
.08).96(12
     8
     —
     16
     16
     —
```

As the number of decimal places in both dividend and divisor are equal, the point would come after the 12 and would of course be useless.

Divide 4.5 by 12.2

```
12.2)4.5000(.368+
     3 66
     ————
      840
      732
      ————
      1080
       976
      ————
       104
```

As there are four decimal places in dividend and one in the divisor we point off three places, which brings the point before the 3 as shown.

Table of decimal equivalents on next page.

DECIMAL EQUIVALENTS OF AN INCH.

		1/4	.25	1/2	.5	3/4	.75
1/64	.015625	17/64	.265625	33/64	.515625	49/64	.765625
1/32	.03125	9/32	.28125	17/32	.53125	25/32	.78125
3/64	.046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.09375	11/32	.34375	19/32	.59375	27/32	.84375
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.15625	13/32	.40625	21/32	.65625	29/32	.90625
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.21875	15/32	.46875	23/32	.71875	31/32	96875
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375

Conventional Rule for Square Root.

(For explanation of principle on which the rule is founded see chapter beginning on page 60.)

Separate the given number into periods, by pointing every second figure, beginning with the unit's place.

Find the greatest square in the left hand period and place its root on the right; subtract the square of this root from the first period and to the remainder bring down the next period for a dividend.

Divide this dividend, omitting the last figure, by double the root already found, and annex the result to the root and also to the divisor, multiply the divisor as it now stands, by the figure of the root last obtained, and subtract the product from the dividend.

If there are more periods to be brought down, continue the operation in the same manner as before.

Example:

What is the square root of 144?

$$\begin{array}{r|l} & \dot{1}4\dot{4}(12 \\ & 1 \\ \cline{2-2} 22 & 44 \\ & 44 \end{array}$$

The greatest square in the left hand period or 1, is 1. Subtracting leaves nothing and bringing down the next period gives 44 for the new dividend. Doubling the root already found gives 2 for a trial divisor and trying this in the first figure of the new dividend gives 2 for the next root figure. Annexing this to the trial divisor gives 22 for the true divisor and multiplying by 2 gives 44, coming out even in this case. Sometimes several trials are necessary.

(For explanation of principle on which the rule is founded, see chapter beginning on page 73).

Separate the given numbers into periods, by pointing every third figure, beginning with the unit's place.

Find the greatest cube in the left hand period and place its root on the right; subtract the cube of this root from the left hand period and to the remainder bring down the next period for a dividend.

Divide this dividend, omitting the last two figures, by three times the square of the root already found; annex the quotient to the root.

Add together the trial divisor, with two ciphers annexed, three times the product of the last root figure by the rest of the root, with one cipher annexed; and the square of the last root figure.

Multiply the divisor, as it now stands,

by the figure of the root last obtained, and subtract the product from the dividend.

If there are more periods to be brought down, continue the operation in the same manner as before.

Example:

What is the cube root of 1728 ?

	$\dot{1}72\dot{8}$(12
	1
300	728
60	
4	
364	
	728

By following the rules closely in the manner illustrated in the square root example, there will be no difficulty in understanding the operation.

Formulas.

As it is well to become familiar with the tools we are to use, the following signs are given, with their meanings, before we proceed to use them.

π called "pi" $=3.1416$, which is the circumference of a circle whose diameter is 1. This can be 1 inch, 1 foot or 1 mile, and the circumference will be 3.1416 inches, feet or miles as the case may be.

$d^2=d$ squared or multiplied by itself.

$d^3=d$ cubed or multiplied by itself twice, $d^4=d$ fourth, etc.

The small figures at top are called exponents.

$\sqrt{\ }=$square root and denotes that the square root is to be extracted from the number following it; when bar extends over other figures, it applies to all beneath it, thus $\sqrt{2+7}=3$ (square root of sum.) This can also be represented by $\sqrt{(2+7)}=3$ as before, the brackets showing that all

within them are to be taken as one quantity. $\sqrt{9}+2=3+2=5$, as the root is only taken from first figure because the sign does not extend over the other figures.

$\sqrt[3]{\ }$=cube root, $\sqrt[4]{\ }$=fourth root, $\sqrt[5]{\ }$=fifth root, etc. Fourth root can be found by extracting square root twice.

$\therefore$=Therefore.

The signs must be carefully watched, as all depends on interpreting them correctly; care will do this, however, and strict attention should be paid to it.

Formulas are such a useful feature in the arithmetic of the mechanic, or perhaps it would be more correct to say abbreviation or condensation of the arithmetic, that they should be better known and appreciated by him, as they will shorten his calculations and help him to become much more familiar with the rules used in standard practice among mechanics and engineers. Knowing from a fairly long shop experience that shopmen as a rule seem to have a horror of all formula, imagining them difficult or puzzling and

only useful in confusing those who have not had opportunities in mathematical education, we wish to show how useful formulas are, how they shorten calculation, how they economize space, and that they are much more convenient to remember than long-winded rules, and wish to make them clear even at the risk of being too elementary in the explanations. There seems no better way of making their simplicity evident than by showing how they are *made*, how they are *used*, and their *advantages*, ending with illustrations from everyday practice.

To begin with, a formula is simply an arithmetical rule in which all words are omitted, all the quantities represented by letters and figures, and all the operations are indicated by signs and by the position of the different characters.

We learn from our arithmetic that the area of a rectangle (a figure whose opposite sides are parallel and whose angles are right angles) is found by multiplying one side by the other, or calling one side A and the other B, we can say "A multiplied by B equals the area." To go a

little farther, to call $A=10$ inches, $B=20$ inches, then the area will equal $A(10) \times B(20)=200$ square inches.* To state this correctly we say:

Let A=short side of rectangle.
" B=long " " "
" C=area " " "

Then $C=A \times B$.

As one of the handy features of all formula is the ease of transposition, or of changing the "rule" to find any one quantity, the others being given, we can show this nicely in this simple case and shall do so as we proceed with other problems. We might have the area and the short side given to find the long side or the area and long side given to find the short side. Then as $C=A \times B$,

---

*It is evident that the area will be in square measure of whatever unit the sides are; in this case square inches. The multiplication sign is not necessary between letters, as A and B in this case, and is often omitted, $C=A\,B$ meaning that C=prcduct of A B. In some English works multiplication is denoted by a period where we usually place the decimal point, their decimal point being placed half way up the figure as A.B means $A \times B$, while 3·5=3.5 or $3\frac{1}{2}$.

$$B = \frac{C}{A} \text{ an } A = \frac{C}{B},$$

or in figures, $C = 10 \times 20 = 200$, $B = \frac{200}{10} = 20$ and $A = \frac{200}{20} = 10$. Going now to another case we take the circle and learn that the relation between the diameter and the circumference is as 1 to 3.1416 (near enough for practical purposes), or in other words, that a circle 1 inch in diameter has a circumference of 3.1416 inches, or one of 2 inches has a circumference of 6.2832 inches, so we say: Diameter (d) multiplied by 3.1416 equals circumference in the same measure or unit as the diameter, or $d \times 3.1416 = c$ or circumference. This relation has come to be known as "pi" and represented by π, which means that the sign π stands for the number 3.1416 as $\pi d = 3.1416 \times$ diameter, which of course equals the circumference or periphery. Having a pulley 10 inches in diameter, making 200 revolutions, per minute, we wish to find how fast the rim is traveling in feet per minute. The circumference equals 10×3.1416 (diameter $\times\ \pi$) $= 31.416$ inches, which, divided by 12, gives 2.618 feet. Now to make our formula we say:

d=diameter in inches.

π=3.1416.

c=circumference in inches.

$$\text{Then } d\times\pi=c \text{ or } \frac{d\times\pi}{12}=c \text{ in } \textit{feet.}$$

As it is running 200 revolutions per minute, 200×2.618=523.6 feet per minute, or combining this in the formula and adding r=revolutions per minute and F=feet per minute that rim travels, to above notation we have

$$F=\frac{cr}{12} \text{ or,}$$

$$F=\frac{d\times\pi\times r}{12} \text{ or } \frac{d\pi r}{12} \text{ or } \frac{cr}{12}=$$

$$\frac{10\times3.1416\times200}{12} \text{ or } \frac{31.416\times200}{12}=523.6$$

feet per minute.

This can be transposed to find any of the quantities and as we wish to be thorough in all we do, we transpose as follows:

$$c=d\times\pi, \text{ and } d=\frac{c}{\pi}, \quad F=\frac{d\times\pi\times r}{12} \text{ or } d=12\frac{F}{\pi\times r}$$

because, d being in inches and F in feet,

it is evident that the speed in feet, divided by "pi" times revolutions, must be multiplied by 12 to reduce it to inches. Then

$$r=\frac{F\times12}{\pi\times d}=\frac{523.6\times12}{3.1416\times10}=\frac{6283.2}{31.416}=200$$

and with these three transpositions of the formula any desired factor can be obtained.

Taking the area of the circle next we learn that the diameter squared (multiplied by itself) and multiplied by the constant number .7854 gives the area. The area of a cylinder 12 inches in diameter will then be $12\times12\times.7854=113.09$ square inches; calling the diameter d, and a the area, we say $d^2\times.7854=a$.

What is the total pressure on a steam piston 10 inches in diameter, steam pressure 100 pounds per square inch? In this case $d=10$, then $d^2\times.7854=10\times10\times.7854=78.54\times100=7854$ pounds total pressure on piston. Now taking a cylinder twice this diameter, with the same pressure, we then have $20\times20\times.7854=314.16\times100=31{,}416$ pounds of total pressure, or *four* times the former case, although the diameter is only *twice* as

large. This brings us to the "law of squares," which is simply that *areas of similar figures vary as the squares of similar dimensions*, diameter in this case, the other cases will come later. This shows that in any cylinder, tube or shaft, the areas vary as the square of the diameters, and that a 2 inch tube has four times the area of a 1-inch tube, or a 3 inch cylinder has 9 times the area of a 1-inch cylinder (because $3\times 3=9$, while $1\times 1=1$), while the areas of two holes, 3 and 5 inches respectively, are as $3\times 3=9$ and $5\times 5=25$, or as 9 is to 25, or if one will pass 9 cubic feet of air or water per second, the other will pass 25.

Having found the area of a shaft, we have only to multiply this by the length to find the volume of cubical contents, and knowing this, we can estimate very closely the weight of different substances, by multiplying the number of cubic inches it contains by the weight of one cubic inch of the material.

Putting this into a short formula we have:

d= diameter in inches.

l=length in inches, or $\frac{l}{12}$ = length in feet.

c=constant.

Then $d^2 \times .7854 \times l \times c$ = weight of any round shaft or bar.

What will a steel shaft 2 inches in diameter and 10 feet long, weigh? Referring to table of weights of metal in Kent's Pocket Book, we find steel given as .283 pounds per cubic inch—then in this case c=.283 Then $2 \times 2 \times .7854 \times 10 \times 12 \times .283 = 106.68$ pounds as weight of shaft. Transposing once more we find that as $d^2 \times .7854 \times l$ = cubical contents (a), then

$$d = \sqrt{\frac{a}{.7854 \times l}}$$

or square root of

$$\frac{376.99}{.7854 \times 120}$$

376.99 being the cubical contents of the shaft in question.

This must now be solved, and the square root of this result equals d. In the same way we transpose for l, when

$$l=\frac{a}{d^2\times.7854}$$

If a shaft must have a certain weight, first divide this by the weight per cubic inch, which will give the required cubical contents, and the result can easily be found by the formulas given. Of course we can transpose the whole formula, including weight, but it would only add to the number of formulas without being necessary.

Before going on with useful shop formula, let us take a "horrible example" and see how it is solved, which will perhaps clear up some of the mysteries better than the simple formulas. Taking

$$A=\frac{b}{2}\sqrt{a^2-\left(\frac{a^2+b^2-c^2}{2b}\right)^2}$$

where $a=3$, $b=5$, $c=4$. The fraction being enclosed in the brackets, indicates that it is to be considered as *one* quantity, and after being squared, subtracted from a^2, and the square root of this difference multiplied by

$$\frac{b}{2};\text{ or }\sqrt{9-\left(\frac{9+25-16}{2\text{x}5}\right)^2}$$

Taking the fraction, $\left[\frac{9+25-16}{2\times5}\right]^2$, we have $\frac{34-16}{2\times5}=\frac{18}{10}=1.8$ Then squaring 1.8 we have 3.24 Subtracting this from 9, gives 5.76, and square root of this is 2.4 which multiplied by

$\frac{b}{2}$, which is $\frac{5}{2}$, gives $2.4\times\frac{5}{2}=6=A$.

If the brackets included all the figures under the vinculum (bar from the square root sign) the calculations would be

$$\sqrt{\left[9-\frac{9+25-16}{2x5}\right]^2}$$

$\sqrt{(9-1.8)^2} = \sqrt{7.2^2} = 7.2 = A$, so that special care must be taken to follow the signs correctly. These particular points will be shown as we proceed.

Taking the formula for the area of a ring where $A=.7854\ (D^2-d^2)$

D=outer diameter.

d=inner diameter.

A=area in square measure of whatever unit the diameters are given in, if D and d are inches, A will be square inches, etc.

$D=10$ inches, $d=6$ inches. Then $A=.7854\times(D^2-d^2)$. The brackets denote

that this part must be solved first. $10 \times 10 = 100$, $6 \times 6 = 36$, $100 - 36 = 64$. $A = .7854 \times 64 = 50.26$ square inches. By adding l=length; to the formula we can find the cubical contents and weight of any hollow cylinder or pipe, and calling this one 12 inches long we have $50.26 \times 12 = 602.6$ cubic inches, from which weight can be found for any material.

As an example of working backwards, find the thickness of a cast iron cylinder whose outer diameter is 10 inches, length 15 inches, and which must weigh 200 pounds. Cast iron is given as .26 pound per cubic inch. So dividing 200 by .26 we find that ($200 \div .26 = 769.23$) 769.23 cubic inches are necessary to make the required weight. Dividing this by the length, 15 inches, we have 51.28 square inches as the area of the ring whose outer diameter is 10 inches. Then we can say $51.28\ (A) = .7854 \times (100 - d^2)$ and transposing we have

$$d = \sqrt{D^2 - \frac{A}{.7854}} = \sqrt{100 - \frac{51.28}{.7854}} = \sqrt{34.71} = 5.89$$

inches internal diameter.

Mensuration.

This can be called the measuring or computing of surfaces, areas and volumes of bodies, and is very useful to the mechanic in many ways. Taking a triangle first, figure 1, as this has the least number of sides of any figure; we discover that all the sides and angles are equal, hence it is called an equilateral triangle. Either half of it, as laid out by the dotted vertical dividing line, is called a right angled triangle because it contains one right angle.

A right angle is one formed by two lines perpendicular to each other or with an opening of 90 degrees or one-quarter the number of degrees of a complete circle.

This can be more readily seen in figure 2, if we take O as a center, and note that the four angles G O E, E O H, H O F, and F O G are all equal, and all are right angles.

The base of a triangle or other figure can be defined as the side on which it rests, in the case of figure 1. the base of the equilateral triangle A B C is the line B C, and half the base will of course be C D or D B.

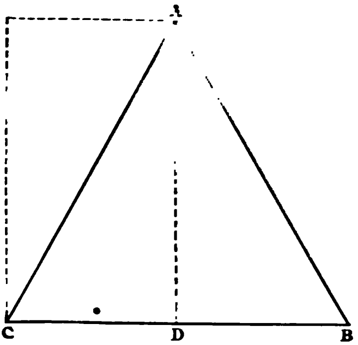

FIG. 1.

The vertical height is shown by the line A D, and can be defined as a line perpendicular to the base and connecting it to the point or apex.

It is plain that if we took the right hand side and placed it on the upper left hand, as shown by the dotted lines, we have made a rectangle and that the area

Calling the steam pressure 120 pounds per square inch, the cylinder 12 by 30 inches and the revolutions 100 per minute, we prepare to find the horse power by the formula. Supposing steam is cut off at ¼ stroke, the mean average pressure on the piston will be about 60 per cent. of the boiler pressure; 60 per cent. of 120 is 72 pounds.

The area of a 12-inch piston equals 113 square inches and 30 inches equals 2½ or 2.5 feet. Then, after remembering that 100 revolutions means 200 strokes, we are ready to say: $P = 72$; $L = 2.5$; $A = 113$, and $N = 200$, which becomes

$$\frac{72 \times 2.5 \times 113 \times 200}{33000} \text{ and equals}$$

123 + horse power.

One of the advantages of formulas over rules is the ease of transposing to find any of the parts composing it. Take the horse power formula and see how easily it works.

$$H\,P = \frac{P \times L \times A \times N}{33000} \text{ as already stated.}$$

Now suppose we have an engine which must develop a certain horse power. The size of the cylinder and the number of strokes are fixed. What must the mean effective pressure be?

Transposing the formulas to read

$$P = \frac{H\,P \times 33000}{L \times A \times N}$$

To find area of piston in square inches

$$A = \frac{H\,P \times 33000}{P \times L \times N}$$

To find the length of stroke in feet

$$L = \frac{H\,P \times 33000}{P \times A \times N}$$

To find the number of strokes per minute

$$N = \frac{H\,P \times 33000}{P \times L \times A}$$

This is much easier than altering rules to suit each case.

Boiler Horse Power.

The evaporation of 34½ pounds of water per hour from and at 212 degrees into steam at 70 pounds pressure is the standard for boiler horse power. In plain English this means that if a boiler evaporates 34½ pounds of water at 212 degrees into steam at 70 pounds pressure in one hour, it is a one horse power boiler.

Feed water is very rarely 212 degrees, more apt to be 60 or 70 degrees and steam at exactly 70 pounds is not often used, so that corrections are necessary for various cases. With temperature of feed water 100 degrees, 30 pounds of water evaporated into steam at 70 pounds pressure is a rated horse power.

To find the evaporation of any case:—
Subtract the heat units in one pound of feed water from the heat units in one

pound of steam and divide this by 966. Multiply this by the weight of water evaporated, and the result is the "equivalent evaporation."

Suppose a boiler evaporates 1500 pounds of water per hour from a feed temperature of 80 degrees into steam at 100 pounds—what is the equivalent evaporation and what horse power is the boiler?

Looking at the steam table on page — we find that the feed water contains 48.04 heat units and the steam 1185 heat units. Subtracting 48.04 from 1185 we have $1185 - 48.04 = 1136.96$. Dividing it by 966 gives 1.17. This 1.17 is called the factor of evaporation and means that the equivalent evaporation is 1.17 times the actual.

Multiplying 1500 by 1.17 gives 1755 pounds evaporated from and at 212 degrees. Dividing this by 34½ gives 50.87 horse power.

The heating surface of a boiler depends on the type of boiler in question. It consists of flues or tubes, a portion of the shell or the firebox surface in an internally fired boiler.

Tubes—

As all boilers have tubes, they are taken first. Calling the tubes 2 inches outside diameter, as this is the side almost universally considered, we first find the circumference by multiplying by 3.1416 and get 6.2832 inches, as we have seen before. Multiplying this by 12 we have 75.4 square inches per foot of length. Dividing this by 144 we have .523 square feet. Multiplying this by 10 feet (if that is the length of flue) we have 5.23 square feet for each flue, and multiplying by the number of flues gives the total flue heating surface.

Or, instead of finding the surface per foot of length, we could find the surface of one flue by multiplying 6.2832 by 120 inches (the length of flue in inches) and get 753.984 square inches, which divided by 144 gives 5.23 square feet per flue, as before.

Shell—

In externally fired boilers we count one-half the shell and one-half the head. Some count on more than this, but it is safer not to calculate too high. You can find the area of half the shell just as we did that of the flues, while the head is easy to figure, being one-half a circle. Internally fired boilers of the locomotive type have the flues and the interior surface of the firebox as heating surface. The flues are calculated the same as before and the firebox surface is easily obtained when the length, width and height are known. All of this is not

equally effective, but this is allowed for in the table of heating surface per horse power which follows:

Heating Surface Per Horse Power.

Types of Boilers—Stationary.

Vertical	15 to 20 square feet
Locomotive	12 to 16 square feet
Horizontal Return Tubular	15 square feet
Water Tube	10 to 12 square feet
Flue	8 to 12 square feet
Plain Cylinder	6 to 10 square feet

With the intense draft used in locomotive practice a horse power is sometimes produced for 1.5 to 3 square feet heating surface.

Indicator calculations are easily under stood. The steam forces the piston up the distance depending on the spring used, and the mark of the pencil show the steam pressure in the cylinder at th different points of the stroke.

Taking the diagram shown in Fig. 8 divide it into any number of equal parts say 10, and measure the hight of each line as shown. Add these together and divide by the number of lines; multiply this by the spring used. This will be th average forward pressure, from which deduct the back pressure. The differ ence is the mean effective pressure.

If you have a planimeter for measur ing the diagram it is easier, as well a more accurate. The regular planimete gives the area of the card or diagram i square inches. Divide this by the lengt of the diagram in inches, which will giv the average hight. This multiplied b

the spring used gives the pressure on every square inch of the piston.

Springs are numbered according to the pressure required to compress them enough to move the pencil one inch vertically. An 80 spring will show 1½ inches in hight on the diagram for 120

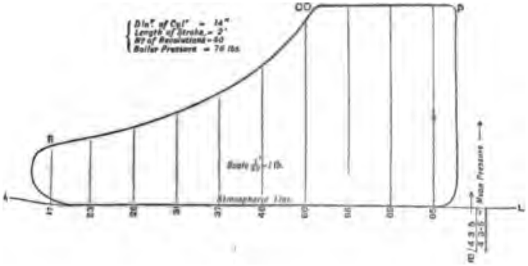

FIG. 8.

pounds pressure. A diagram taken with a 60 spring will be 2 inches high at the same pressure, and so on. Multiplying the average hight by the spring used gives the mean effective pressure on each square inch of piston. Multiplying this by the area of the piston and by the piston speed and dividing the whole by 33000 gives the horse power.

Principles of Square Root.

It may easily be imagined that once upon a time some person while investigating mathematical problems, possibly with nothing better than a handful of pebbles for instruments, made the great (for the time) discovery that while twelve times twelve pebbles was one hundred and forty-four pebbles, that one-half of twelve times one-half of twelve pebbles was not *one-half* of one hundred and forty-four pebbles, but was *one-quarter* of one hundred and forty-four pebbles. It may also be easily imagined that this mathematical investigator arrived at this conclusion by putting his pebbles in twelve rows of twelve each, and six rows of six each, forming two *squares*, one of which was evidently four times the size of the other by eye measurement, as well as containing four times as many pebbles by actual count.

After he had made a few of these *squares* it probably occurred to him that when he went to the post-office to get one hundred postage stamps, it wasn't necessary for him to count the whole hundred, but simply to count and see if he had ten on each *side* of his *square;* and finally, he probably fell into the unconscious habit of performing simple mental operations in extracting *square root*, by asking himself perhaps something as follows: "Now, I want to make a box to hold 144 eggs, each egg to be in a compartment by itself, the box to be a *square* box; how many compartments on each *side* of the *square* box must I have to hold the 144 eggs? Why 12, of course."

About this time Euclid made the discovery that in a right-angled triangle the square of the hypothenuse is equal to the sum of the squares of the other two sides of the triangle.

That is, if one *square* of 36 pebbles is placed in such a position regarding another *square* of 64 pebbles, that two of their *sides* form a right-angled triangle, it will be seen that one side of another

square of 100 pebbles will exactly form the hypothenuse or third side of the triangle, the square of 100 pebbles being equal to the sum of both the other squares; that is, 36 and 64 make a total of 100 (see the figure on page 76, each small square representing a pebble).

Now, it *might* be that what is true of a right-angled triangle of the above dimensions, would not be true of any other triangle. If we take two squares, for instance, of 25 and 16, the sum of which is 41, we cannot come to any conclusion whatever on this particular question, because we cannot arrange our 41 pebbles in the form of a square.

But Euclid proved to a dead certainty that this would hold true, no matter what quantities or numbers entered into the problem, and to deal with this and other things to follow it is now necessary to begin to consider the idea of *unity;* that is *one;* one pebble, one *bushel* of pebbles, one *barrel* of pebbles, one *half* ton of pebbles, one *half* of a pebble. That twice *one* are *two;* twice one *pebble* are *two* pebbles; twice one bushel *two* bushels; twice

one barrel *two* barrels; twice one half ton *two* half tons; twice one half of a pebble *two* halves of a pebble; whether actually in two pieces or in the form of one whole pebble. Every thing in the world taken together makes *one* world; the smallest pebble in the world may be considered as being composed of two halves, four quarters, or a thousand thousandths, or in any other way we choose. to divide it, or may be considered as *one half* of *two* pebbles.

. The truth that in a right-angled triangle, the square of the hypothenuse is equal to the sum of the squares of the other two sides being accepted, it of course follows that if we can find some way to calculate just what the side of a square of these 41 pebbles would be, supposing that they were ground to powder and put in a square, or when the number is too large to make an easy mental calculation (as when you count the sheet of 100 stamps), we can solve many problems that come up in machine shops, such for instance as the exact angle to set a grinding machine to grind a cutter for screw

threads, supposing that the cutter is to be held in a holder made to hold the cutter with a standard *clearance.* In other words, many problems coming up in fine machine work, necessitating a knowledge of how to *extract square root.*

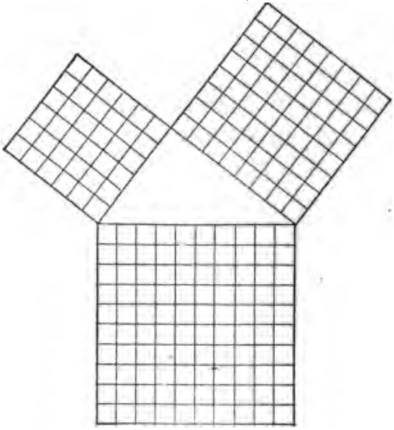

FIG. 8.

Some of these investigators found while playing with their pebbles that the law of squares was a universal law; that his square of 12 pebbles on a side was *always* 144 pebbles, whether he *considered* it as 12 on a side, or 11 and 1 on a side,

or 10 and 2 on a side, or 9 and 3 on a side, and so on through the scale, and they also found that when they did consider their sides of squares as being made up of two quantities, that a universal law held good that the square was always made up as follows: The square of one quantity, plus twice one quantity multiplied by the *other*, plus the square of the *other* quantity; or in the algebraic language representing one quantity (no matter which or what size) by a, and the other by b, then the square of a plus b is equal to a square, plus two a b, plus b square, or in algebraic signs $(a+b)^2=a^2+2\,a\,b+b^2$.

Let us try and see how it comes out, considering 12 as 11 and 1 (or 11 plus 1).

11 squared	121
Twice 11 times 1	22
1 squared	1
Total	144

Considering 12 as 10 plus 2:

10 squared	100
Twice 10 times 2	40
2 squared	4
Total	144

Considering 12 as 9 plus 3:

9 squared	81
Twice 9 times 3	54
3 squared	9
Total	144

Having found out how the square is made up, it is easy enough to pull it to pieces again, or in other words to *extract the square root*, by simply reversing the process by which it was considered the square was made up.

Before proceeding further, we must understand one simple law of multiplication and division—multiplication being simply *supplying* a certain *quantity* a certain number of *times*, same as our ancient friend did when he *supplied* 12 *pebbles* 12 *times* to make his 144 pebbles; and division being simply the *taking away* a certain quantity a certain number of times.

Supplying 12 pebbles 12 times is multiplying 12 by 12, and dividing 144 by 12 is taking 12 lots of 12 pebbles from 144 pebbles, in which case we have no pebbles remaining in the original lot of 144. It follows then, that when a certain quantity is made up by multiplying two *other quan-*

tities together, if the certain quantity is *divided* by either of the *other two quantities* that went to make it up, that the result must be *the other one of the two quantities*; that is if we multiply 4 by 5, making 20, if we divide 20 by 5 the result *must be* 4, or if we divide 20 by 4 the result *must be* 5.

We can now pick the square 144 to pieces as follows, assuming it to be made up of sides of 11 and 1:

Take away from 144 the square of 11:

	144
The square of 11	121
	23 remaining

Take from the 23 remaining the square of 1:

	23
The square of 1	1
	22 remaining

Take away from 22 twice 11 times 1:

	22
Twice 11 times 1	22
	00

Assuming the square 144 to be made up of sides of 10 and 2:

Take from 144 the square of 10:

144
The square of 10........100
44 remaining

Take from the 44 remaining the square of 2:

44
The square of 2.......... 4
40 remaining

Take from 40 twice 10 times 2:

40
Twice 10 times 2 40
00

It will be found that *any* square can be made up and pulled down in the same way; of course it is simple enough when we know how it is made up, to pull it down again.

Now, as it is an accepted custom (*not a mathematical principle*) that numbers increase in value by ten for each place to the left as they are written, let us consider that 144 is the square of something composed of *units* and *tens* (we already *know* it to be composed of *one ten* and *two units*, but this knowledge must not enter into the operation which we are

about to perform), and as the square of units *cannot* be greater than tens (9 largest unit, 81 its square), and as the square of tens cannot be greater than thousands (99 largest ten, 9801 its square), we will separate the number 144 into tens and thousands (these being the squares of units and tens) by following the custom of "pointing off" from the units number into "periods of two figures each."

We have now divided our lot of 144 pebbles, if you please, into two lots (or "periods"), one lot consisting of 100 pebbles and the other lot consisting of 44 pebbles (or 4 tens pebbles and 4 units pebbles), simply because it is *customary*, as explained before, to write numbers in units, tens, hundreds, etc., etc.

The left-hand "period" of 1, then, represents a *unity of hundreds*, that is *one* hundred—*one* hundred pebbles. Let us take away from this period of 1 (no matter now cne *what*) *the largest square there is in it*, which is evidently 1, *we have now pulled out the square of the tens of which the square number 144 was made up.* That is, we have extracted the square

root of all the tens making up the thousands "period" and find it to be *one ten;* we will therefore put down this one ten thus: 1, *not forgetting that it stands in the* TENS PLACE

Now let us go back to the principle of multiplication and division as touched on before:

Having found what the square root of the tens is, and knowing the way that the square is made up, we can now deal with the remaining 44.

Having considered the *root* to have been made up of *units* and *tens*, let us call the tens a and the units b, and look at the algebraic formula again: $(a+b)^2=a^2+2\,a\,b+b^2$.

We have already dealt with the a^2 and set down its root a, in the form of a figure 1 (in the tens place), and now considering the remaining 44 as being also units and tens (4 units and 4 tens), let us see what we can do towards picking out the $2\ a\ b$ of the algebraic formula. We know what the a is; it is 1, and if we divide the tens of the remaining 44 by $2\,a$ (which in this case is 2), it will give us a

hint of what b is; thus we get a hint that b is 2; we therefore consider that it is 2, and see how the experiment comes out. Having already taken away the square of the tens, which is the a^2 of the formula, if b is 2, and we multiply it by itself, it will give us 4 units and fulfill the b^2 of the formula, and if we multiply it by 2 a, which is 20, it will give us twice the tens multiplied by 2 or the 2 a of the formula, this being in this case 40, or 4 *in the tens place.*

That is, the $2\ a\ b+b^2$ of the formula is made up of 2 a multiplied by b, and b multiplied by b, which is of course b^2, and, referring back to the *principle* of multiplication and division explained before, dividing the $2\ a\ b$ of the formula by the 2 a, which we already know, *must* give us the b, *if* the number 144 is a perfect square, which we know it to be in this case.

Practically if no number can be found by trial that will meet the conditions of b, the largest that will go must be taken, and the remainder considered as a decimal fraction, and the operation repeated until the root is extracted as far as wanted.

The correctness of this is manifest when we consider that one ten is equal to ten units, and one unit is equal to ten tenths, and one tenth to ten hundredths, etc., each place to the left increasing the value of a figure, the decimal point having no value, but simply shows where *unity begins*.

A comparison of these principles and explanations, step by step with the operation of extracting square root as done by the conventional rule, cannot fail to make the subject clear; and when once the sub ject *is* clear, there is less liability of mistakes when doing a problem by the rule, to say nothing of the advantage of being able to get along without the rule if the book is mislaid or the memory weak. When the principle of extracting roots is once mastered it is a fascinating amusement as well as valuable practice, to extract 4th, 5th, 6th, etc., roots for which no rules are usually to be found.

Principles of Cube Root.

Assuming that it is understood how a *square* is made up and the principle on which square root is extracted, as explained in the previous chapter on *square root.*

We will proceed to investigate the manner in which a *cube* is constructed. The cube of 12 (12 times 12 times 12, or as expressed in signs, 12×12×12) is 1,728, and considering that the 12 is composed of 10 and 2 (on account of the *custom* of giving a value of ten times what the figure itself represents, for each place to the left occupied by the figure, as explained in the chapter on square root), we find the cube of 1,728 to be made up as follows:

10 cube, - - - - - - -	1,000
3 times 10 square times 2, - -	600
3 times 10 times 2 square, - -	120
2 cube, - - - - - - -	8
Total, - - - - -	1,728

"Pointing off" the number 1,728 into "periods of three" (for the same reason that we point off into periods of two in square root), we proceed to extract the largest cube from the left hand period, in this case 1, the cube root of which is evidently 1 also, so that we now know we have found the 1 *ten* that went to make up the cube 1,728, and as the cube of the 1 *ten* is 1,000 we now must consider the remaining 728, which we know to be made up 3 times 10 square times 2, plus 3 times 10 times 2 square, plus 2 cube, as shown before. But as two is the number we are now seeking for, we must now assume that we do not know what it is, in order to be able to find it when we really do not know in actual practice.

Whether it is 2 or any other number we know it cannot be a very large number, as it *must* be *units* (as we have already found what the cube root of the *tens* is), and cannot therefore be over 9.

It follows then that the remaining 728 must be made up *principally* of 3 times 10 square, plus 3 times ten, multiplied by something which will make *nearly* 728,

and by using this 3 times 10 square, plus 3 times 10, for a *trial divisor*, we get a *hint* of what the "something" wanted is.

As this sum (330) will go into 728 a little over twice, we think that 2 is the number we are looking for, and to see if it really is the number we want, we must carry it through with the rest and see how we come out.

As we know the remaining 728 to be made up of 3 times 10 square times 2, plus 3 times 10 times 2 square, plus 2 cube, we know also that if we remove the factor 2 from these quantities, that is divide them by 2, we shall obtain a quantity, which, being multiplied by 2, will give us the original quantities back again; this being self-evident.

Dividing these quantities by 2, we obtain 3 times 10 square (the 2 left out) plus 3 times 10 times 2 (one of the 2's left out) plus 2 *square* (one of the 2's left out again).

By making a divisor of the sum of these quantities, which amount to 364, we find it goes exactly twice into the remaining 728, and therefore know that 2 is

really the *units* figure that we have been looking for.

To reduce to a formula: The cube of $a+b$ is $a^3+3a^2b+3ab^2+b^3$ ($a=10$ and $b=2$ in this case), after taking away the a^3 we evidently have remaining $3a^2b+3ab^2+b^3$. As we do not know what b is, we take $3a^2+3a$, which is what remains with the b left out altogether, for a *trial* divisor, and by assuming the approximate quotient to be the b that is sought, we take $3a^2+3ab+b^2$, which is $3a^2b+3ab^2+b^3$ *divided* by the b, and multiply it by the b back again, to see if the b we have assumed is really the b we have been looking after.

In the case of 1728 we find that it completes the cube, and that b is really 2 and so know that we are right.

Therefore (knowing that we are right), if there should be a remainder after taking the result of this final multiplication out of what is left of the original number, we would know that the number was not a perfect cube, and would take what is left and annex ciphers for another period, or as many more periods as required for the degree of accuracy needed, same as in square root.

To be thoroughly independent of *rules* for extracting roots (and a great many other mathematical calculations as well), we must consider the idea of *factors.*

When we multiply 3 by 2 we have 6 for a result, and we say 3 and 2 are *factors* of 6; multiplying again by 2 we get 12, and say that 6 and 2 are *factors* of 12, or we can say that 2 and 2 and 3 are factors of 12; or multiplying 12 by 12 we get 144 and say that 12 and 12 are factors of 144, or we can say that 2 and 2 and 2 and 2 and 3 and 3 are factors of 144, this being represented in arithmetical signs as follows:

$$2\times 2\times 2\times 2\times 3\times 3=144.$$

This is called an *equation* because something is represented as being *equal* to something else.

If we start and reverse the operation and divide 144 by 2 we have 72 as a result, and find that *one less* 2 on the left

hand side will make the equation true, thus:

$$2 \times 2 \times 2 \times 3 \times 3 = 72.$$

That is, we can take away one of the factors 2 from the left hand side of this equation, and divide the right hand side by 2, and still have an *equation*: that is, one side will still be *equal* to the other side.

It follows then, that by taking one of the factors 2 from the left hand side, and dividing the right hand side by 2, we have done the same thing to both sides, because if we had not, they would no longer be equal.

That is, dividing 144 or any other number, by 2 or any other number, is simply taking the factor 2 (or whatever other number it may be), from the first number, no matter how the first number is represented.

Or in other words, taking the quantity $2 \times 2 \times 2 \times 2 \times 3 \times 3$ (which we happen to know is equal to 144) and removing one of the factors 2 from it, we have *divided* the *whole quantity* by 2.

A little more reasoning along this same line will show us that *dividing a*

factor by a certain number divides the whole quantity by that number, or multiplying a factor by a certain number (or quantity) multiplies the whole quantity by that number (or quantity).

In arithmetic we can consider a certain number as representing a certain thing; that is, we can take the number 1, and consider that it stands for 1 ton of coal, and after going through our calculations, we know that the result, whatever it is, is also to be considered as tons of coal. So in algebra, a certain sign or letter may be considered as a certain number or quantity of anything and the sign or letter is multiplied or divided, etc., through the calculation, and when the calculation is completed, we know that this sign or letter represents in the result the same thing that it did at the start: If we say that a represents a ton of coal, and when the calculation is completed, we have a result of 144 a, we know that this means 144 tons of coal.

It would be easy enough to carry the number 1 through any calculation (no matter now whether 1 ton of coal or 1

something else), but if we had the number 1,083,729,524,982, to deal with it would be quite a task to carry it through a long calculation. A slight knowledge of algebra allows us to consider that a or b, or c, represents this large number, or any other number, or thing, and carry the *letter* through a calculation (it is *customary* to use the first letters of the alphabet to represent *known* quantities, and the last letters of the alphabet to represent *unknown* quantities, but it is not necessary to follow this custom, as we can as well use a picture of a ton of coal, to represent the ton of coal, or the above number of tons of coal, if we only stick to the same thing until the calculation is finished).

If then we had a large number like the above to deal with, it would evidently by easier to say in starting:

$$a=1,083,729,524,982$$

and take the a through the calculation; then if for instance we got $3a$ as the result of the calculation, we would know that 3 times 1,083,729,524,982 was our answer, thus being obliged to multiply this large number but once in the whole calculation,

which reduces the chances of error, as well as being easier and quicker.

In algebra, contrary to arithmetic, the position to the right or left, of a letter or sign has nothing to do with its value, and two or more letters side by side means that these letters are *multiplied together*, or in other words that they are *factors.*

The expression "aa" then, means that a, whatever it represents, is multiplied by a, and if we assume that a represents 12, we then know that "aa" represents 144.

But as any quantity multiplied by itself becomes *square*, the expression "aa" is equivalent to the expression "a square," and for the same reason the expression "aaa" is also evidently equivalent to the expression "a cube."

It is easier and quicker (besides being customary) to write a square thus, a^2, instead of "aa", and a cube, a^3, instead of "aaa".

When this is understood, we can take another step and instead of saying $a=12$, we can say $a=10$ and $b=2$, then we can

go ahead and say a plus $b=12$ or usir the regular arithmetical sign for plus (a dition) we write it thus:

$$a+b=12$$

It then follows that $a+b$ multipli by itself will be equal to 12 multiplied l itself, or in other words that $a+b$, squar is equal to 12 square, and that (knowir 12 square to be 144) $a+b$, square, equal to 144.

We can now multiply the expressic $a+b$ by itself, the operation being ve much like multiplication of numbers arithmetic:

First (as in arithmetic) we set tl quantities to be multiplied one under tl other thus:

$$\begin{array}{c} a+b \\ a+b \\ \hline \end{array}$$

b multiplied by b will evidently (fro what has already been explained) becon b square, written b^2, so after the result this first step is written down, the calcul tion would appear thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline b^2 \end{array}$$

Multiplying a by b would give us ab which we also set under the line, same as in arithmetic, thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \end{array}$$

We have now multiplied $a+b$ by b and must start to multiply $a+b$ by a as follows:

b multiplied by a is evidently ab (the *position* of the factors not altering their value, so for convenience in adding we write it ab instead of ba) so (also for convenience in adding) we set this ab under the other ab which we got a first by multiplying a by b, thus:

$$\begin{array}{l} a+b \\ a+b \\ \hline ab+b^2 \\ ab \end{array}$$

And a multiplied by a is evidently a^2, which we also set down thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \\ a^2+ab \end{array}$$

We now (same as in arithmetic), add

the results of multiplication togethe[r]
the answer: ab added to ab is evid[ently]
two ab, which is written "$2ab$," so
the complete operation now appears:

$$\begin{array}{r}
a+b \\
a+b \\
\hline
ab+b^2 \\
a^2+ab \\
\hline
a^2+2ab+b^2
\end{array}$$

$a^2+2ab+b^2$ is the formula giv[en in]
the chapter on "square root" on p[ages]
77 and 82.

By multiplying this again by [$a+b$]
we will evidently get the *cube* of [$a+b$],
which is the formula used in the artic[le on]
cube root, thus:

$$\begin{array}{r}
a^2+2ab+b^2 \\
a+b \\
\hline
a^2b+2ab^2+b^3 \\
a^3+2a^2b+ab^2 \\
\hline
a^3+3a^2b+3ab^2+b^3
\end{array}$$

If we should multiply this aga[in by]
$a+b$ we should get a formula which w[ould]
allow us to extract the *fourth* root[, and]
so on.

A thorough understanding of t[his]

foundation principles, and of the previous chapters on square root, and cube root, makes us independent of any written rules for extracting square, cube, or *any other* root.

When squaring (or multiplying it by itself) any mixed number (whole number and a fraction) whose fraction is $\frac{1}{2}$ it is well to know that this can be done mentally as follows:

Add *one* to one number, multiply by the other, and add $\frac{1}{4}$ to answer.

Take $3\frac{1}{2} \times 3\frac{1}{2}$; $3+1=4$, $4 \times 3=12 + \frac{1}{4}=12\frac{1}{4}$ answer. Or $9\frac{1}{2} \times 9\frac{1}{2}=9 +1=10 \times 9=90+\frac{1}{4}=90\frac{1}{4}$.

A quick and easy way to divide any number by $12\frac{1}{2}$ is:

Multiply by 8 and "point off" two places.

Example: $\frac{250}{12\frac{1}{2}}=250 \times 8=2000$ and pointing off two places (always from the right) we have 20.00 as the answer.

A handy rule for squaring any number mentally is:

Subtract the number from the next higher *tens* number, subtract the difference

from the original number; multiply this result by the *tens* number used and add the square of the difference.

This sounds hard but it isn't, and can be readily acquired so that any number up to 100 can be squared mentally, easily and quickly.

Take 17, the next higher *tens* number is 20. 20—17=3. 17−3=14. 14×20=280. 3 squared=3×3=9. 280+9=289, the square of 17.

Take 26. Next higher *tens* number is 30. 30—26=4. 26—4=22. 22×30=660. 4×4=16. 660+16=676, the square of 26.

One more example will show its use in squaring large numbers.

Take 81. Next higher *tens* number is 90. 90—81=9. 81—9=72. 72×90=6480. 9×9=81. 6480+81=6561, the square of 81.

This is a larger number than it is often necessary to square mentally, but a little practice makes it an easy matter, and it's often handy in comparing areas of pipes and cylinders.

Wrought Iron Pipe Sizes.

The difference between nominal and actual diameters of wrought iron pipe, as well as the peculiar system of threads, makes a table necessary if you want to know what to count on in making calculations.

All iron pipe is designated by its nominal inside diameter. The table gives pipe up to five inches.

WROUGHT IRON PIPE TABLE.

Nominal.	Inside.	Outside.	Threads per inch.	Tap Drill.
1/8	.27	.40	27	$\frac{21}{64}$
1/4	.36	.54	18	$\frac{29}{64}$
3/8	.49	.67	18	$\frac{19}{32}$
1/2	.62	.84	14	$\frac{23}{32}$
3/4	.82	1.05	14	$\frac{15}{16}$
1	1.05	1.31	11 1/2	$1\frac{3}{16}$
1 1/4	1.38	1.65	11 1/2	$1\frac{15}{32}$
1 1/2	1.6	1.9	11 1/2	$1\frac{23}{32}$
2	2.06	2.37	11 1/2	$2\frac{3}{16}$
2 1/2	2.47	2.87	8	$2\frac{11}{16}$
3	3.06	3.5	8	$3\frac{5}{16}$
3 1/2	3.55	4.	8	$3\frac{13}{16}$
4	4.	4.5	8	$4\frac{5}{16}$
4 1/2	4.5	5.	8	$4\frac{3}{4}$
5	5.05	5.56	8	$5\frac{5}{16}$

Brief Glossary of Terms Used in Steam Engineering.

Absolute Pressure:—

Pressure above a perfect vacuum, obtained by adding 14.7 to gage pressure at sea level. This decreases as the altitude increases; 100 pounds boiler pressure would be 114.7 pounds absolute.

Absolute zero:—

This point is 460 degrees Fahrenheit below zero, or 492 degrees below the freezing point.

Adiabatic Expansion:—

Expansion taking place without heat transmission. In practice this never happens, and the isothermal expansion is much nearer correct.

Air Pump:—

Pump used to remove cooling water and condensed steam from hot well of condenser.

Boiler Pressure:—

Steam pressure as registered by the steam gage. This is the pressure above

that of the atmosphere which at sea level is 14.7 pounds per square inch above a perfect vacuum or absence of pressure.

Boyle's Law:—

See Mariotte's Law.

British Thermal Unit:—

Same as Heat Unit.

By-Pass:—

An arrangement of pipes for diverting all or a portion of the steam, air or water, as the case may be, from its regular course if occasion demands.

Calorie:—

French thermal unit. The quantity required to 1 kilogramme of pure water 1 degree Centigrade at about 4 degrees Centigrade which is equivalent to 39.1 Fahrenheit. One calorie = 3.968 British thermal units and 1 British thermal unit = .252 calorie.

Circulating Pump:—

Pump to circulate cooling water in surface condensers or similar places.

Compound Engine:—

A multiple expansion engine of two stages. The low pressure or second stage may be divided between two or more cylinders. See Multiple Expansion.

Condenser:—

Apparatus for condensing the exhaust to reduce the back pressure below atmospheric pressure, as this adds to the effective pressure on the piston. There are three kinds—jet, surface, and syphon or ejector.

Condenser—Jet:—

In these the steam and water mingle, the resulting hot water going to the hot well. From here it is pumped out by the air pump.

Condenser—Surface:—

Condenser in which the steam does not come in contact with the cooling water. It is usually confined to the space surrounding the tubes through which the cooling water is pumped.

Condenser—Syphon:—

A jet condenser in which the water from the hot well is removed by syphon or ejector instead of a pump.

Condensing Water:—

Water used to condense exhaust steam in any type of condenser. It usually requires from 25 to 30 times the weight of steam to condense it.

Duty of Pumping Engines:—

The number of millions of foot pounds of work they will do for each 100 pounds of coal burned under boiler. Based on assumed evaporation of 10 pounds of water per pound coal so that it is equivalent to work per 1000 pounds of steam.

Electrical Horse Power:—

Any combination of volts and amperes that when multiplied together makes 746. Thus, 75 amperes of current at 100 volts = 7500 watts, or a little over 10 horse power.

Factor of Safety:—

If a boiler of such material and strength that it will stand a pressure of 500 pounds before bursting is run at 100 pounds pressure, the factor of safety is 5. In other words, the proportion between bursting or breaking strength and the pressure or load carried.

Feed Water Heater:—

Apparatus for heating feed water before entering boiler, preferably by utilizing waste heat of exhaust steam or chimney gases.

Foot Pound:—

The raising of one pound one foot in one minute.

Heat Unit:—

Heat required to raise 1 pound of water 1 degree. Taken at the greatest density of water from 39.1 to 40.1 degrees Fahrenheit.

Horse Power:—

Equals 33000 foot pounds per minute, which means 33000 pounds raised one foot in one minute, or 3300 pounds raised 10 feet in one minute or 33 pounds raised 1000 feet in one minute, or 100 pounds raised 330 feet in one minute, or 550 pounds raised one foot in one second; or any combination of feet and pounds which multiplied together make 33000.

Horse Power Constant:—

This may be for any given engine at a fixed speed, and in this case is: "Area of piston × length of stroke in feet × strokes per minute ÷ 33000." This multiplied by mean effective pressure used at any time gives horse power. It may be for some engines at varying speeds. Then it is: "Area of piston × stroke in

feet ÷ 33000; this multiplied by mean effective pressure and strokes per minute = horse power." Or it may be simply for a given cylinder diameter, when it becomes: "Area of piston ÷ 33000." This multiplied by mean effective pressure and piston speed = horse power.

Horse Power Hour:—

One horse power developed continually for one hour.

Inches of Mercury:—

Used in connection with vacuum produced by condensers; 2.04 inches of mercury equals 1 pound pressure per square inch; 29.9 inches of mercury equal atmospheric pressure of 14.7 pounds.

Inches of Water:—

Used in connection with chimney draft; 27.6 inches of water equals 1 pound pressure; 1.72 inches equal 1 ounce pressure; one foot (12 inches) of water equals .434 pounds per square inch.

Initial Pressure:—

Pressure at beginning of stroke.

Injector:—

Instrument utilizing a jet of steam from boiler for forcing water into boiler in place of pump.

Injection Water:—

Water used in jet or syphon (ejector) condensers to effect the condensation of the steam.

Inspirator:—

Same as injector.

Isothermal Expansion:—

The expansion of equal temperature in which the pressure and volume vary inversely. In other words, one increases as the other decreases. Doubling the volume halves the pressure, etc.

Latent Heat:—

The heat required to separate the molecules or particles of water when forming it into steam. At atmospheric pressure this is 965.7 heat units.

Mariotte's Law:—

That pressure and volume vary inversely—as in isothermal expansion. Also called Boyle's law.

Mean Effective Pressure :—

The average forward pressure minus the back pressure. See section on indicators, page 57, and table of average pressures on page 99.

Mechanical Equivalent of Heats:—

The number of foot pounds of mechanical energy contained in one heat unit as these are convertible. The accepted equivalent is that a heat unit equals 778 pounds, falling 1 foot will generate 1 heat unit.

Multiple Expansion:—

Using or expanding steam through more than one cylinder is called multiple expansion. After exhausting the steam from the first or high pressure cylinder it is passed into other cylinders and expanded further. The high pressure cylinder is the smallest. Low pressure is sometimes divided between two or more cylinders. Intermediate cylinders (between high and low) are also sometimes divided.

Quadruple Expansion Engine:—

A multiple expansion engine of four stages. See multiple expansion.

Receiver:—

Steam space between the different cylinders of a multiple expansion engine. This is sometimes a steam drum of considerable size and in other cases merely a space in the pipes or passages.

Receiver Pressure:—

Pressure of steam in receiver. Some jacket the receivers with steam to keep the steam pressure in the receiver. Others allow a drop in pressure. Few engineers now use a steam jacket on the receiver.

Steam Saturated:—

Steam in contact with water or having temperature corresponding to its pressure.

Steam Superheated:—

Steam heated above the temperature, due to its pressure.

Terminal Pressure:—

Pressure at end of the stroke. In a multiple expansion engine the terminal pressure of the first cylinder is the initial pressure of the next, and so on through them all.

Total Heat of Water:—

At atmospheric pressure this is 180.9 heat units. It is the total heat above 32 degrees Fahrenheit, or freezing.

Total Heat of Steam:—

The heat units in the water plus the latent heat. At atmospheric pressure this is $180.9 + 965.7 = 1146.6$.

Triple Expansion Engine:—

A multiple expansion of three stages. See multiple expansion.

Vacuum:—

Absence of pressure. In steam engineering the reduction of pressure below the atmosphere on the exhaust side of the piston in condensing engines.

Water Groove Packing:—

A plan where one or more grooves are turned in the piston or bored in a gland or packing box. Condensed steam collects in these grooves and makes a seal or packing.

Table of Average Pressure for Different Cut-Off.

Point of Cut-Off.	Constant.	Point of Cut-Off.	Constant.	Point of Cut-Off.	Constant.
1	.056	32	.684	59	.900
2	.098	33	.696	60	.906
4	.169	34	.706	61	.911
6	.229	35	.717	62	.916
8	.282	36	.727	63	.92
10	.330	37	.738	64	.926
11	.353	38	.748	65	.93
12	.374	39	.756	66	.934
13	.395	40	.766	67	.938
14	.415	41	.776	68	.942
15	.432	42	.784	69	.946
16	.453	43	.792	70	.949
17	.471	44	.801	71	.953
18	.488	45	.809	72	.958
19	.505	46	.816	73	.959
20	.522	47	.823	74	.962
21	.537	48	.831	75	.963
22	.553	49	.839	77	.969
23	.568	50	.846	80	.978
24	.582	51	.853	82	.982
25	.596	52	.859	85	.987
26	.61	53	.866	87	.99
27	.624	54	.872	90	.994
28	.636	55	.877	92	.995
29	.648	56	.884	95	.996
30	.661	57	.89	97	.997
31	.672	58	.896	100	1.

Multiply the boiler pressure by the constant opposite the point of cut-off in question, deduct back pressure and the result is mean effective pressure. Example: Boiler pressure 100, cut-off 5 8; back pressure 4.3 pounds, what is m. e. p.? 100 x .9181=91.81 pounds average. 91.81—4.3=87.51 mean effective pressure.

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Circumferences of Circles.

These tables are arranged to give all circumferences between ¼ inch and 100¾ inches, varying by ¼. The whole numbers are at the left, fractions at the top. The first column gives circumferences of even inches, as, beside 11 is 34.558. For 11¾ inches follow the same line to the last column, marked ¾ at the top and find 36.914. The circumference of a ½-inch circle is 1.571 inches. These can be used for inches, feet, yards, or meters by remembering that if you look for the circumference of a 7-foot circle the answers are in feet instead of inches.

CIRCUMFERENCES OF CIRCLES.

	¼	½	¾
....	.785	1.571	2.356
3.1416	3.927	4.712	5.498
6.283	7.068	7.854	8.639
9.425	10.21	10.996	11.781
12.566	13.352	14.137	14.923
15.708	16.493	17.279	18.064
18.850	19.635	20.42	21.206
21.991	22.776	23.562	24.347
25.133	25.918	26.704	27.489
28.274	29.06	29.845	30.631
31.416	32.201	32.987	33.772
34.558	35.343	36.128	36.914
37.699	38.485	39.27	40.055
40.841	41.626	42.412	43.197
43.982	44.768	45.553	46.338
47.124	47.909	48.695	49.480
50.265	51.051	51.836	52.622
53.407	54.192	54.978	55.763
56.549	57.334	58.119	58.905
59.69	60.476	61.261	62.046
62.832	63.617	64.403	65.188
65.973	66.759	67.544	68.33
69.115	69.9	70.686	71.471
72.257	73.042	73.827	74.613
75.398	76.184	76.969	77.754
78.54	79.325	80.111	80.896
81.681	82.467	83.252	84.038
84.823	85.608	86.394	87.179
87.965	88.75	89.535	90.321
91.106	91.892	92.677	93.462
94.248	95.033	95.819	96.604
97.389	98.175	98.96	99.746
100.531	101.316	102.102	102.887
103.673	104.458	105.243	106.029
106.814	107.6	108.385	109.17
109.956	110.741	111.527	112.312
113.097	113.883	114.668	115.454

		¼	½	¾
37	116.239	117.024	117.81	118.596
38	119.381	120.166	120.951	121.737
39	122.522	123.308	124.093	124.878
40	125.664	126.449	127.235	128.02
41	128.805	129.591	130.376	131.161
42	131.947	132.732	133.518	134.303
43	135.088	135.874	136.659	137.445
44	138.23	139.015	139.801	140.586
45	141.372	142.157	142.942	143.728
46	144.513	145.299	146.084	146.869
47	147.655	148.44	149.266	150.011
48	150.796	151.582	152.367	153.153
49	153.938	154.723	155.509	156.294
50	157.08	157.865	158.65	159.436
51	160.221	161.007	161.792	162.577
52	163.363	164.148	164.934	165.719
53	166.504	167.29	168.075	168.861
54	169.646	170.431	171.217	172.002
55	172.788	173.573	174.358	175.144
56	175.929	176.715	177.5	178.285
57	179.071	179.856	180.642	181.427
58	182.212	182.998	183.783	184.569
59	185.354	186.139	186.925	187.71
60	188.496	189.281	190.066	190.852
61	191.637	192.423	193.208	193.993
62	194.779	195.564	196.35	197.135
63	197.92	198.706	199.491	200.277
64	201.062	201.847	202.633	203.418
65	204.204	204.989	205.774	206.56
66	207.345	208.131	208.916	209.701
67	210.487	211.272	212.058	212.843
68	213.628	214.414	215.199	215.984
69	216.77	217.555	218.341	219.126
70	219.911	220.697	221.482	222.268
71	223.053	223.838	224.624	225.409
72	226.195	226.98	227.765	228.551
73	229.336	230.122	230.907	231.692

		1/4	1/2	3/4
74	232.478	233.263	234.049	234.834
75	235.619	236.405	237.19	237.976
76	238.761	239.546	240.332	241.117
77	241.903	242.688	243.473	244.259
78	245.044	245.83	246.615	247.4
79	248.186	248.971	249.757	250.542
80	251.327	252.113	252.898	253.684
81	254.469	255.254	256.04	256.825
82	257.611	258.396	259.181	259.967
83	260.752	261.538	262.323	263.108
84	263.894	264.679	265.465	266.250
85	267.035	267.821	268.606	269.392
86	270.177	270.962	271.748	272.533
87	273.319	274.104	274.889	275.675
88	276.46	277.246	278.031	278.816
89	279.602	280.387	281.173	281.958
90	282.743	283.529	284.314	285.1
91	285.885	286.67	287.456	288.241
92	289.027	289.812	290.597	291.383
93	292.168	292.954	293.739	294.524
94	295.31	296.095	296.881	297.666
95	298.451	299.237	300.022	300.807
96	301.593	302.378	303.164	303.949
97	304.734	305.52	306.305	307.091
98	307.876	308.661	309.447	310.232
99	311.018	311.803	312.588	313.374
100	314.159	314.944	315.729	316.515

		¼	½	¾
36	1017.9	1032.1	1046.3	1060.7
37	1075.2	1089.8	1104.5	1119.2
38	1134.1	1149.1	1164.2	1179.3
39	1194.6	1210.	1225.4	1241.
40	1256.6	1272.4	1288.2	1304.2
41	1320.3	1336.4	1352.7	1369.
42	1385.4	1402.	1418.6	1435.4
43	1452.2	1469.1	1486.2	1503.3
44	1520.5	1537.9	1555.3	1572.8
45	1590.4	1608.2	1626.	1643.9
46	1661.9	1680.	1698.2	1716.5
47	1734.9	1753.5	1772.1	1790.8
48	1809.6	1828.5	1847.5	1866.5
49	1885.7	1905.	1924.4	1943.9
50	1963.5	1983.2	2003.	2022.8
51	2042.8	2062.9	2083.1	2103.3
52	2123.7	2144.2	2164.8	2185.4
53	2206.2	2227.	2248.	2269.1
54	2290.2	2311.5	2332.8	2354.3
55	2375.8	2397.5	2419.2	2441.1
56	2463.	2485.	2507.2	2529.4
57	2551.8	2574.2	2596.7	2619.4
58	2642.1	2664.9	2687.8	2710.9
59	2734.	2757.2	2780.5	2803.9
60	2827.4	2851.	2874.8	2898.6
61	2922.5	2946.5	2970.6	2994.8
62	3019.1	3043.5	3068.	3092.6
63	3117.2	3142.	3166.9	3191.9
64	3217.	3242.2	3267.5	3292.8
65	3318.3	3343.9	3369.6	3395.3
66	3421.2	3447.2	3473.2	3499.4
67	3525.7	3552.	3578.5	3605.
68	3631.7	3658.4	3685.3	3712.2
69	3739.3	3766.4	3793.7	3821.
70	3848.5	3876.	3903.6	3931.4
71	3959.2	3987.1	4015.2	4043.3
72	4071.5	4099.8	4128.2	4156.8

		¼	½	¾
73	4185.4	4214.1	4242.9	4271.8
74	4300.8	4329.9	4359.2	4388.5
75	4417.9	4447.4	4477.	4506.7
76	4536.5	4566.4	4596.3	4626.4
77	4656.6	4686.9	4717.3	4747.8
78	4778.4	4809.	4839.8	4870.7
79	4901.7	4932.7	4963.9	4995.2
80	5026.5	5058.	5089.6	5121.2
81	5153.	5184.9	5216.8	5248.9
82	5281.	5313.3	5345.6	5378.1
83	5410.6	5443.3	5476.	5508.8
84	5541.8	5574.8	5067.9	5641.2
85	5674.5	5707.9	5741.5	5775.1
86	5808.8	5842.6	5876.5	5910.6
87	5944.7	5978.9	6013.2	6047.6
88	6082.1	6116.7	6151.4	6186.2
89	6221.1	6256.1	6291.2	6326.4
90	6361.7	6397.1	6432.6	6468.2
91	6503.9	6539.7	6575.5	6611.5
92	6647.6	6683.8	6720.1	6756.4
93	6792.9	6829.5	6866.1	6902.9
94	6939.8	6976.7	7013.8	7051.
95	7088.	7125.6	7163.	7200.6
96	7238.2	7276.	7313.8	7351.8
97	7389.8	7428.	7466.2	7504.5
98	7543.	7581.5	7620.1	7658.9
99	7697.7	7736.6	7775.6	7814.8
100	7854.	7893.3	7932.7	7972.3

PROPERTIES OF SATURATED STEAM.

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO.		Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
		Heat-units per pound of steam.	Heat-units per pound of water.		
1	102	1145	102.1	.0030	20620
2	126.3	1152.5	126.4	.0058	10720
3	141.6	1157.1	141.9	.0085	7326
4	153.1	1160.6	153.4	.0112	5600
5	162.3	1163.4	162.7	.0137	4535
6	170.1	1165.8	170.6	.0163	3814
7	176.9	1167.9	177.4	.0189	3300
8	182.9	1169.7	183.5	.0214	2910
9	188.3	1171.4	188.9	.0239	2607
10	193.2	1172.9	193.9	.0264	2360
11	197.8	1174.2	198.5	.0289	2157
12	202	1175.5	202.7	.0313	1988
13	205.9	1176.7	206.7	.0337	1846
14	209.6	1177.9	210.4	.0362	1722
14.7	212	1178.6	212.9	.0380	1644

15	213.1	1178.9	213.9	.0387	1612
16	216.3	1179.9	217.2	.0413	1514
17	219.4	1180.9	220.4	.0437	1427
18	222.4	1181.8	223.4	.0462	1351
19	225.2	1182.6	226.3	.0487	1282.1
20	227.9	1183.5	229	.0511	1220.3
21	230.5	1184.2	231.7	.0536	1164.4
22	233	1185	234.2	.0561	1113.5
23	235.4	1185.7	236.7	.0585	1066.9
24	237.7	1186.5	239	.0610	1024.1
25	240	1187.1	241.3	.0634	984.8
26	242.2	1187.8	243.5	.0658	948.4
27	244.3	1188.5	245.7	.0683	914.6
28	246.3	1189	247.7	.0707	883.2
29	248.3	1189.7	249.8	.0731	854
30	250.2	1190.3	251.7	.0755	826.8
31	252.1	1190.8	253.6	.0779	801.2
32	254	1191.4	255.5	.0803	777.2
33	255.7	1191.9	257.3	.0827	754.7
34	257.5	1192.5	259.1	.0851	733.5
35	259.2	1193	260.8	.0875	713.4
36	260.9	1193.5	262.5	.0899	694.5

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO.		Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
		Heat-units per pound of steam.	Heat-units per pound of water.		
37	262.5	1194	264.2	.0922	676.6
38	264	1194.5	265.8	.0946	659.7
39	265.6	1195	267.4	.0970	643.6
40	267.1	1195.4	268.9	.0994	628.2
41	268.6	1195.9	270.5	.1017	613.4
42	270.1	1196.3	272	.1041	599.3
43	271.5	1196.7	273.4	.1064	586.1
44	272.9	1197.2	274.9	.1088	573.7
45	274.3	1197.6	276.3	.1111	561.8
46	275.7	1198	277.7	.1134	550.4
47	277	1198.4	279	.1158	539.5
48	278.3	1198.8	280.4	.1181	529
49	279.6	1199.2	281.7	.1204	518.6
50	280.9	1199.6	283	.1227	508.5
51	282.1	1200	284.2	.1251	499.1
52	283.3	1200.4	285.5	.1274	490.1

53	284.5	1200.7	286.7	.1297	481.4
54	285.7	1201.1	288	.1320	472.9
55	286.9	1201.4	289.2	.1343	464.7
56	288.1	1201.8	290.3	.1366	457
57	289.1	1202.1	291.5	.1388	449.6
58	290.3	1202.5	292.7	.1411	442.4
59	291.4	1202.8	293.8	.1434	435.3
60	292.5	1203.2	294.9	.1457	428.5
61	293.6	1203.5	296	.1479	422
62	294.7	1203.8	297.1	.1502	415.6
63	295.7	1204.1	298.2	.1525	409.4
64	296.8	1204.5	299.2	.1547	403.5
65	297.8	1204.8	300.3	.1570	397.7
66	298.8	1205.1	301.3	.1592	392.1
67	299.8	1205.4	302.4	.1615	386.6
68	300.8	1205.7	303.4	.1637	381.3
69	301.8	1206	304.4	.1660	376.1
70	302.7	1206.3	305.4	.1682	371.2
71	303.7	1206.6	306.4	.1704	366.4
72	304.6	1206.9	307.3	.1726	361.7
73	305.6	1207.1	308.3	.1748	357.1
74	306.5	1207.4	309.3	.1770	352.6

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO.		Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
		Heat-units per pound of steam.	Heat-units per pound of water.		
75	307.4	1207.7	310.2	.1792	348.3
76	308.3	1208	311.1	.1814	344.1
77	309.2	1208.2	312	.1836	340
78	310.1	1208.5	313	.1858	336
79	310.9	1208.8	313.8	.1880	332.1
80	311.8	1209	314.7	.1901	328.3
81	312.7	1209.3	315.6	.1923	324.6
82	313.5	1209.6	316.5	.1945	320.9
83	314.4	1209.8	317.3	.1967	317.3
84	315.2	1210	318.2	.1989	313.9
85	316	1210.3	319	.2010	310.5
86	316.8	1210.6	319.9	.2032	307.2
87	317.6	1210.8	320.7	.2053	304
88	318.5	1211	321.5	.2075	300.8
89	319.3	1211.3	322.4	.2097	297.7
90	320	1211.6	323.2	.2118	294.7

91	320.8	1211.8	324	.2139	291.8
92	321.6	1212	324.8	.2161	288.9
93	322.4	1212.3	325.6	.2183	286.1
94	323.1	1212.5	326.4	.2204	283.3
95	323.9	1212.7	327.1	.2225	280.6
96	324.6	1213	327.9	.2245	278
97	325.4	1213.2	328.7	.2267	275.4
98	326.1	1213.4	329.4	.2288	272.8
99	326.8	1213.6	330.2	.2309	270.3
100	327.6	1213.8	331	.2330	267.9
101	328.3	1214	331.7	.2351	265.5
102	329	1214.3	332.4	.2372	263.2
103	329.7	1214.5	333.1	.2392	260.9
104	330.4	1214.7	333.9	.2413	258.7
105	331.1	1214.9	334.6	.2434	256.5
106	331.8	1215.1	335.3	.2455	254.3
107	332.5	1215.3	336	.2475	252.2
108	333.2	1215.6	336.7	.2496	250.1
109	333.9	1215.8	337.4	.2517	248
110	334.5	1216	338.1	.2538	246
111	335.2	1216.2	338.8	.2558	244
112	335.9	1216.4	339.5	.2579	242

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO. Heat-units per pound of steam.	CALCULATED FROM ZERO. Heat-units per pound of water.	Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
113	336.5	1216.6	340.2	.2599	240.1
114	337.2	1216.8	340.8	.2620	238.2
115	337.8	1217	341.5	.2640	236.3
116	338.5	1217.2	342.2	.2661	234.5
117	339.1	1217.4	342.8	.2682	232.7
118	339.7	1217.6	343.5	.2702	231
119	340.4	1217.8	344.2	.2722	229.3
120	341	1217.9	344.8	.2743	227.6
121	341.6	1218.1	345.4	.2763	226
122	342.2	1218.3	346.1	.2783	224.4
123	342.9	1218.5	346.7	.2803	222.8
124	343.5	1218.7	347.3	.2823	221.2
125	344.1	1218.9	348	.2843	219.7
126	344.7	1219.1	348.6	.2862	218.2
127	345.3	1219.3	349.2	.2882	216.7
128	345.9	1219.4	349.8	.2902	215.2

129	346.5	1219.6	350.4	.2922	213.7
130	347.1	1219.8	351.1	.2942	212.3
131	347.6	1220	351.7	.2962	210.9
132	348.2	1220.2	352.3	.2982	209.5
133	348.8	1220.4	352.9	.3001	208.1
134	349.4	1220.5	353.5	.3021	206.7
135	350	1220.7	354.1	.3040	205.4
136	350.5	1220.9	354.6	.3060	204.1
137	351.1	1221	355.2	.3080	202.8
138	351.7	1221.2	355.8	.3099	201.5
139	352.2	1221.4	356.4	.3119	200.2
140	352.8	1221.5	357	.3139	199
141	353.3	1221.7	357.5	.3159	197.8
142	353.9	1221.9	358.1	.3179	196.6
143	354.4	1222	358.7	.3199	195.4
144	355	1222.2	359.2	.3219	194.2
145	355.5	1222.4	359.8	.3239	193
146	356	1222.5	360.4	.3259	191.9
147	356.6	1222.7	360.9	.3279	190.8
148	357.1	1222.9	361.5	.3299	189.7
149	357.6	1223	362	.3320	188.6
150	358.1	1223.2	362.6	.3340	187.5

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO. Heat-units per pound of steam.	CALCULATED FROM ZERO. Heat-units per pound of water.	Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
151	358.7	1223.3	363.1	.3358	186.4
152	359.2	1223.5	363.6	.3376	185.3
153	359.7	1223.7	364.2	.3394	184.3
154	360.2	1223.9	364.7	.3412	183.3
155	360.7	1224	365.2	.3430	182.3
156	361.2	1224.1	365.8	.3448	181.3
157	361.8	1224.3	366.3	.3467	180.3
158	362.3	1224.4	366.8	.3485	179.3
159	362.8	1224.6	367.3	.3503	178.3
160	363.3	1224.8	367.9	.3521	177.3
161	363.8	1224.9	368.4	.3540	176.4
162	364.3	1225	368.9	.3558	175.5
163	364.8	1225.2	369.4	.3577	174.6
164	365.2	1225.3	369.9	.3596	173.7
165	365.7	1225.5	370.4	.3615	172.8
166	366.2	1225.6	370.9	.3634	171.9

167	366.7	1225.8	371.4	.3652	*171*
168	367.2	1225.9	371.9	.3671	170.1
169	367.7	1226.1	372.4	.3690	169.2
170	368.2	1226.2	372.9	.3709	168.4
171	368.6	1226.4	373.4	.3727	167.6
172	369.1	1226.5	373.9	.3745	166.8
173	369.6	1226.7	374.4	.3763	166
174	370	1226.8	374.9	.3781	165.2
175	370.5	1226.9	375.4	.3799	164.4
176	371	1227.1	375.9	.3817	163.6
177	371.4	1227.2	376.2	.3835	162.8
178	371.9	1227.4	376.8	.3853	162
179	372.4	1227.5	377.3	.3871	161.2
180	372.8	1227.7	377.8	.3889	160.4
181	373.3	1227.8	378.3	.3908	159.7
182	373.7	1227.9	378.7	.3926	159
183	374.2	1228.1	379.2	.3944	158.3
184	374.6	1228.2	379.7	.3962	157.6
185	375.1	1228.3	380.1	.3981	156.9
186	375.5	1228.5	380.6	.3999	156.2
187	376	1228.6	381.1	.4017	155.5
188	376.4	1228.7	381.5	.4036	154.8

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	CALCULATED FROM ZERO.		Weight in decimals of a pound per cubic foot.	Specific volume, or volume of 1 cu. ft. of water in steam.
		Heat-units per pound of steam.	Heat-units per pound of water.		
189	376.9	1228.9	382	.4054	154.1
190	377.3	1229	382.4	.4072	153.4
191	377.7	1229.1	382.9	.4090	152.7
192	378.2	1229.3	383.3	.4108	152
193	378.6	1229.4	383.8	.4125	151.3
194	379	1229.5	384.2	.4143	150.7
195	379.5	1229.7	384.7	.4160	150.1
196	380	1229.8	385.1	.4178	149.5
197	380.3	1229.9	385.6	.4196	148.9
198	380.7	1230.1	386	.4214	148.3
199	381.1	1230.2	386.5	.4232	147.7
200	381.6	1230.3	386.9	.4250	147.1

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